The coefficient of differential galactic absorption

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I. Introduction and Summary.

Several investigators have found that the light of the stars near the galactic plane is absorbed in interstellar space. The observational facts are explained by the hypothesis that the absorbing material is very much concentrated toward the galactic plane. A summary of these investigations is in section V. 5.

It is the object of the present paper to test the hypothesis described above and to determine the amount of the differential galactic absorption per unit of distance by means of the color indices of the stars in the vicinity of the sun.

SECTION II: The colors of the stars of a given spectral class depend on the absolute magnitude. This relation between color and absolute magnitude is found, independently of the absorption, by means of the stars in the direction of the galactic pole outside the assumed absorbing layer. The absolute magnitude effect being known, the colors of the stars near the galactic plane are reduced to the same absolute brightness and the differential galactic absorption is found from the relation between color and distance of the stars near the galactic plane. The change of the color index per unit of absolute magnitude as well as the differential absorption per unit of distance have been derived from stars of the same apparent magnitude and position. Any systematic error in the observed color indices therefore, depending on the apparent magnitude and the position is eliminated from the results for the change of color with absolute magnitude and distance.

The height of the absorbing layer has been taken equal to 100 parsecs on either side of the sun, which is somewhat larger than the value found by VAN DE KAMP (see section V. 5).

SECTIONS III. 1 to 3: The present investigation is based on the color indices enumerated in table 1; the areas used are in figure 1. The distances have been computed from the mean parallaxes $\pi(m, \mu)$ of the stars of given proper motion, apparent magnitude, spectral class and galactic latitude derived in Gron. Publ. **34** as well as from the observed spectroscopic absolute magnitudes. The distances of the stars used in the present investigation do not exceed 500 parsecs.

SECTIONS IV. 1 to 3: The relation between color index and absolute magnitude for stars of a given spectral class is taken to be linear for a range of three units of absolute magnitude. The results for α_e, representing the change of the color index per unit of absolute magnitude, are in table 3; a negative sign of α_e means that the absolutely bright stars are redder than the absolutely faint ones. The color system to which the results for α_e are reduced is Göttingen photographic minus Harvard visual magnitude [1]).

A comparison with the absolute magnitude effect derived by STICKER [2]) is given in section IV. 3, table 8. The differences between STICKER's values and

[1]) For reference see table 1.

[2]) Veröffentlichungen Bonn **23**, 1930.

ours are very probably due to the differential absorption which has affected STICKER's results.

SECTIONS V. 1 to 5: The final adopted value for the differential absorption per unit of distance is:

$$\beta_g = + \cdot 050 \pm \cdot 003 \text{ (p.e.) mag/100 ps;}$$

this value is reduced to the color system $c =$ Mt Wilson photographic minus Harvard visual magnitude (see section V. 4).

The value of β_g found for the separate galactic areas of figure 1 and separate spectral types are in the tables 9, 11, 12 and 13.

The mean value of β_g for all spectral classes together is not changed appreciably if it is assumed that the color does not depend on the absolute magnitude at all and all values α_e are therefore taken equal to zero. This is due to the fact that the absolute magnitude effect as found in this paper is of opposite sign for the F and G stars on the one hand and the K stars on the other hand; the mean value of the absorption for all spectral classes is therefore not changed by taking α_e equal to zero for all spectral classes instead of the values „α_e adopted" given in table 7. If we adopt the absolute magnitude effect as found by STICKER the absorption is reduced to $\beta_g = + \cdot 026$ mag/100 ps.

The value of β_g found from the photoelectric color indices observed by BOTTLINGER and BECKER [1]) for separate spectral types are in table 14. We have adopted the values α_e derived by BECKER [2]). On the assumption of $\alpha_e = \cdot 000$ for all spectral classes we find nearly the same value for β_g as in the case of α_e adopted according to BECKER. BECKER's positive absolute magnitude effect for the B and A stars is cancelled by the negative effect for the G, K and M stars in the mean value of β_g for all spectra together.

The results from different galactic areas show a larger absorbing power of the galactic layer for the galactic longitudes 90° and 270° than for the longitudes 10°, 170° and 235°. A comparison with the values of β_g derived by other investigators is given in the section V. 5. The effective thickness of the absorbing layer computed from the optical thickness found by VAN DE KAMP [3]), STEBBINS [3]) and VYSSOTSKY and WILLIAMS [3]) amounts to 220 ± 10 ps.

SECTIONS VI. 1 and 2 contain the description of the derivation of the proper motions used in the Göttingen and the Cape Astrographic Zone [1]). The proper motions in the Cape Astrographic Zone have been derived in a graphical way.

In SECTION VI. 3 the relation between the color systems used in the present investigation has been discussed.

In the SECTION VI. 4 some details are given of the computation of a systematic error introduced in the observed mean color indices by the selection of these colors on the basis of the amount of the proper motion or the observed absolute magnitude.

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1) See table 1.

2) Zeitschrift für Astrophysik **5**, 107, 1932.

3) For reference see table 16, page 33.

My thanks are due to professor VAN RHIJN for his valuable advice and criticism during the course of this investigation and for his kindness to place some of his unpublished investigations at my disposal; to the computing staff of the Kapteyn Laboratory and especially to Mr. H. J. Smith and Mr. W. Ebels for their efficient help in the computations involved in this investigation.

II. Outline of the method and the reductions.

As has already been stated in the introduction a value for the differential galactic absorption per unit of distance will be derived in this paper from the color indices of the stars in the vicinity of the sun.

The method rests upon the following working hypothesis: The material, responsible for the interstellar absorption, occurs in a layer of a thickness of about 100 ps on either side of the sun and parallel to the galactic plane; the material has a uniform density for distances parallel to the galactic plane < 500 ps (compare section V. 5).

It will be shown that a reliable value for the differential absorption per unit of distance can be found on the basis of this hypothesis.

We consider first stars lying outside the absorbing layer, called extragalactic stars.

Suppose, all these stars have practically the same apparent magnitude, spectral class and position on the celestial sphere. The stars of this group near the sun are absolutely fainter than the more distant ones. The absorption being the same for all objects of the group, the color indices are supposed to depend on the absolute magnitude only:

$$c_e = \alpha_e M_e + \gamma_e \tag{1}$$

where:

c_e is the mean observed color index of the extragalactic stars having a mean absolute magnitude M_e [1]).

α_e is the increase in color index per magnitude; α_e depends on the spectral class only.

γ_e is the same for all stars of a spectrum-apparent magnitude group.

The range of absolute magnitudes used in the same spectrum-apparent magnitude group never exceeds 2 units. Within this interval the relation between color index and absolute magnitude as found by STICKER [2]) and BECKER [3]) may be represented for each spectral class by a straight line.

We consider in the second place a number of stars lying within the absorbing layer. If these galactic stars have practically the same apparent magnitude, spectral class and position, their color indices will depend on the absolute magnitude as well as on the distance; therefore:

$$c_g = \alpha_e M_g + \beta_g r_g + \gamma_g \tag{2}$$

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[1]) The absolute magnitude, used in this paper, is defined by: $M = m + 5 + 5 \log \pi$.

[2]) Veröff. Bonn **23**, 18, 1930.

[3]) Z. f. Astrophys. **5**, 107, 1932.

where:

c_g is the mean color index of the galactic stars having distances between the narrow limits r_1 and r_2.

M_g is the mean absolute magnitude of these galactic stars.

r_g is the mean distance of these galactic stars.

β_g is the differential absorption per unit of distance.

γ_g is the same for all stars of a spectrum-apparent magnitude group.

It can be shown that the mean color index depends linearly on the distance if the absorption is due to a cloud of constant density.

The absolute magnitude effect α_e being known from the stars outside the absorbing layer (equation (1)) the coefficient of differential absorption β_g can be found from the stars inside the absorbing layer (equation (2)). This method has the advantage that the errors in the observed color indices depending on the apparent magnitude and the position on the celestial sphere are eliminated because all stars from which the absolute magnitude effect and the differential absorption are derived have practically the same apparent magnitude and position.

According to equations (1) and (2) the differences between the colors of the galactic and extragalactic stars of the same spectral class and absolute magnitude are supposed to be due only to the differential absorption. We therefore make the assumption that the distribution of the colors of the stars of given spectral class and absolute brightness is the same in every part of the stellar system.

In the practical application of the method the stars have been divided into galactic areas between $-10°$ and $+10°$ galactic latitude [1]) and the extragalactic areas with a galactic latitude between $\pm 40°$ and $\pm 90°$. The distances used in the present investigation never exceeding 500 parsecs the radiation of the stars within the galactic belt $-10°$ to $+10°$ passes the assumed absorbing layer of 200 parsecs thickness along its entire path [2]).

The coefficient α_e in the equation (1) has been found from the stars in the extragalactic areas. The objects in each area are distributed into groups according to spectral type and apparent magnitude, the range being one unit of spectral class and 1 magnitude respectively. Each spectrum-apparent magnitude group is divided into subgroups containing stars at practically the same distance from the sun, the range in distance being about 30 parsecs. Each subgroup gives a relation of the form (1), from which the coefficient α_e is solved by the method of least squares.

The coefficient α_e has been computed from stars with a distance exceeding 100 parsecs; if the galactic latitude of the center of the extragalactic area is smaller than 70° a somewhat larger limit has been adopted. The stars lie therefore outside the assumed absorbing layer.

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[1]) Throughout this paper we have used professor VAN RHIJN's tables of galactic coordinates given in Gron. Publ. **43**, tables 2 and 3, 1929. VAN RHIJN's galactic circle (pole: $\alpha_{1900} = 12^h56^m$, $\delta_{1900} = +25°.5$) is defined as the curve of maximum apparent density of the stars between the apparent magnitudes 8 and 18.

[2]) We assume the sun to be centrally located in the sheet of absorbing material.